Chapter 4

Remote Experiments in Freshman Engineering Education by Integrated e-Learning

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ABSTRACT

Information communication technologies (ICT) have made it possible to introduce Integrated e-Learning (INTe-L) as a new strategy for teaching physics in engineering education. It is based on the methods that the sciences use for the cognition of the real world. INTe-L utilizes the e-laboratory which consists of remote experiments, e-simulations, and e-textbooks. Its main features include observations of real world phenomena, possibly materialized in data and their evaluation, the search for relevant information, its classification and storing. Only then come the explanation and the mathematical formalism of generalized laws and their consequences. Essential to this method is the active part the student must take in the learning process: in lessons, seminars, and laboratory exercises, but also his/her substantially increased activity in form of projects, search for information, presentations, et cetera.

In this chapter, we present the outlines of the remote laboratory integrated in the INTe-L system, using the Internet School Experimental System (ISES) as hardware and an ISES WEB Control kit as software. We suggest an architecture for implementing remote laboratories, with data transfer across the Internet, based on standard and reusable ISES modules as hardware and Java supported ISES software. The Learning Management System (LMS) MOODLE turns out to be a highly effective means of organization of physics courses. The first experience on teaching units Free fall (http://remotelab4.truni.sk), Simple Pendulum (http://remotelab5.truni.sk), and Natural and driven oscillations (www.ises.info – see Remote laboratory) is presented.

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INTRODUCTION

The physics teaching methods at secondary schools and universities are at a critical stage in their development. The traditional way of delivering physics in an overwhelming majority of physics courses has characteristics we are familiar with. Most of the class time involves the teacher lecturing to students; assignments are typically homework problems with short quantitative answers. Seminars and especially laboratory work are more or less "recipe" style, usually only loosely bound to the time schedule of the lectures, and examinations are largely based on written exams containing theory and a bit of problem solving (Wieman & Perkins, 2005). Over the past couple of decades, physics education researchers have studied the effectiveness of these practices including extensive conceptual understanding, transfer of information and ideas from teacher to student in a traditional physics lecture, and beliefs about physics and problem solving in physics (McDermott & Redish, 1999; Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006; for reviews with useful citations, see references in Wieman & Perkins, 2005). The definitive conclusion is that no matter the quality of the teacher, typical students in a traditionally taught course are learning mechanically, memorizing facts and recipes for problem solving, and are not gaining a true understanding. Equally alarming is that in spite of the best efforts of teachers, typical students are also learning that physics is boring and irrelevant to understanding the world around them, including their future professions.

The impetus for the development of most new emerging teaching technologies is the desire to remove the barriers to students' independent and exploratory work in all sorts of laboratories for the purpose of elucidating the real world (Wieman & Perkins, 2005; Thomsen, Jeschke, Pfeiffer & R. Seiler, 2005; Feisel & Rosa, 2005). The main development, with few dissenting voices against this trend, was to bring about a change in physics laboratories in the direction of substituting research laboratories for the "recipe labs" (Domin, 1999). It is useful to refer to the1977 document of the American Association of Physics Teachers which formulated five goals the physics laboratory should achieve (American Association of Physics Teachers, 1990):

- **The Art of Experimentation:** The introductory laboratory should engage each student in significant experiences with experimental processes, including some experience designing investigation.
- **Experimental and Analytical Skills:** The laboratory should help the student develop a broad array of basic skills and tools of experimental physics and data analysis. Computers, when used as flexible tools in the hands of students for the collection, analysis, and graphical display of data, can accelerate the rate at which students can acquire data, abstract, and generalize from real experience with natural phenomena. The digital computer is an important tool for an inquiry based course in physics because it has become the most universal tool of inquiry in scientific research. However, computer simulations should not be used as substitutes for direct experience with physics apparatus.
- **Conceptual Learning:** The laboratory should help students master basic physics concepts. The use of computers with laboratory interfaces allows real-time recording and graphing of physical quantities. The qualitative use of real-time graphing in computer-based laboratories has increased interest in using the laboratory to enhance conceptual understanding. The combination of two factors — laboratory course design based on an understanding of the preconceptions that students bring to the study of physics from their past experience, and the continuing development of

laboratory technology — has the potential to significantly improve the effectiveness of laboratory instruction.

- **Understanding the Basis of Knowledge in Physics:** The laboratory should help students understand the role of direct observation in physics and to distinguish between inferences based on theory and the outcomes of experiments.
- **Developing Collaborative Learning Skills:** The laboratory should help students develop collaborative learning skills that are vital to success in many livelong endeavours.

Since 1977, ICT and computers have invaded all aspects of physics teaching. The present state of ICT development is characterized by the quantitative analysis of data in a way that leads to very deep changes in qualitative understanding. In an editorial to a recent issue of *European Journal of Physics* devoted to student undergraduate laboratory and project work, Schumacher (2007) brings examples of the intrusion of computers into contemporary laboratory work including project labs, modelling tools, interactive screen experiments, remotely controlled labs, etc., and closes with the plausible statement, "One can well imagine that project labs will be the typical learning environment for physics students in the future."

The present discussion about new teaching methods in physics is no longer directed towards fundamental changes in learning processes due to the new ICT, but rather how to introduce these new techniques into everyday teaching practice by establishing the resources of e-learning, curricula, etc. With this contribution, we intend to contribute to this discussion, introducing new technology and strategy for physics education based on ideas that the sciences use for their study of the real world–i.e. exploration, discovery and ICT- the Integrated e-Learning.

The layout of the chapter is as follows. First, we want to give the motivation and pedagogical reasoning for INTe-L and how its components - remote e-experiments, e- simulations and e-textbooks - contribute to its goals. Second, we want to introduce the architecture and modules of the suggested scheme of remote experiments using the Internet School Experimental System (ISES) as hardware and an ISES WEB Control kit as software. The simplicity and applicability of the suggested architecture and INTe-L strategy with the first pedagogical experiences are then demonstrated by examples of teaching units in Mechanics. In the outlook part of the chapter we point out the preparatory steps of collaborative remote experiments in LMS (Maiti, 2010; Bochicchio & Longo, 2009), leading to the Socratic laboratory envisaged by Hake (1998). We intend to introduce the "short" and " long" range feedback by the usage of clickers in the lectures and seminars within INTe-L strategy (Perkins & Turpen, 2009) and on the other hand in tests, using the average normalized gain <g> as the measure of the effectiveness (Hake, 2007) of the INTe-L process.

Motivations and Pedagogical Reasoning for INTe-L

The first motivation for our work was very practical - the decreasing level of physics education and the reduced popularity of physics subjects among students. Physics is one of the most formidable subjects in primary and secondary schools as well as in technical universities, resulting not only in a decreasing level of physics knowledge (McDermott & Redish, 1999) but in decreasing hours allotted to physics education. This trend, which has lasted for two decades, might be attributed to the way physics is presented to younger generations.

The second motivation for INTe-L came from the inspiring papers of Wieman (Wieman & Perkins, 2005; Wieman, Adams & Perkins, 2008), supporting and calling for a change in educational technology, while seeing the remedy at hand in the existence of simulations. Towards this purpose, the University of Colorado at Boulder started a very instructive Internet site PhET with many applets, covering the usual scope of physics topics. Thomsen and his co-workers introduced a new approach called e-LTR (eLearning, eTeaching, eResearch) using remote experiments (Thomsen, Jeschke, Pfeiffer & R. Seiler, 2005). Introducing eResearch, based on the e - laboratory, which is composed of remote Internet mediated experiments, they filled the missing link of e-Learning (Cikic, Jeschke, Ludwig, Sinha & Thomsen, 2007). Also very inspiring was the pioneering of RCL (Remotely controlled laboratories) in Kaiserslautern, Germany by Jodl (Gröber, Vetter, Eckert & Jodl, 2008).

The third motivation came from our own work over the last two decades in computer-oriented hands-on experiments and remote experiments. We realized that the existence of the computer oriented experiments based on the ISES system (see www.ises.info) and remote experiments built on the same system (Schauer, Lustig, Dvořák & Ožvoldová, 2008a) enable the introduction of a new strategy of education utilizing these new teaching tools. On top of this, for implementing remote laboratories we suggest the use of standard and reusable ISES modules as hardware and Java supported pre-prepared ISES software.

We introduced INTe-L with the following definition (Schauer, Ožvoldová & Lustig, 2009a): “INTe-L is the interactive strategy of teaching and learning based on the observation of real world phenomena by real e-experiments and e-simulations and on the principal features of the physic laws. It includes e-teaching tools as interactive e-textbooks and manuals and instructions which provide information and theoretical background for the understanding and quantification of observed phenomena”.

It is fair to note that the INTe-L introduced in our laboratory and defined in this way has very many common features of blended learning (Procter, 2003) by combining face-to-face instruction with computer-mediated instruction. This terminology has been refuted by some, pointing out that the term may be used for almost any form of teaching containing two or more different kinds of things that can then be mixed (Oliver & Trigwell, 2005) but not stressing the role of remote experiments and simulations. INTe-L differs substantially from the process integrated e-learning introduced several years ago (Jørgensen, Rolfsen & Krogstie, 2004) stressing the role of practical activities only. The integration of INTe-L into the teaching of physics is very demanding, attainable only with the decisive support of ICT as it is based on the following: remote Internet experiments in e-laboratories for real world phenomena observations (Gröber, Vetter, Eckert & Jodl, 2007); Java or Flash applets in the form of e-simulations, as for instance in PhET at the University of Colorado at Boulder (http://phet.colorado.edu/new/index.php) for the dynamic animations; and e-textbooks (Ožvoldová et al. 2007; Schauer 2008b, INTe-L MOODLE Course in the Faculty of Informatics, Tomas Bata University in Zlin, Mechanics, http://vyuka.fai.utb.cz/login/index.php). With this in mind, we want to present the first results of the combined effort of several universities in the Czech and Slovak Republics with the integration of INTe-L.

Components of INTe-L

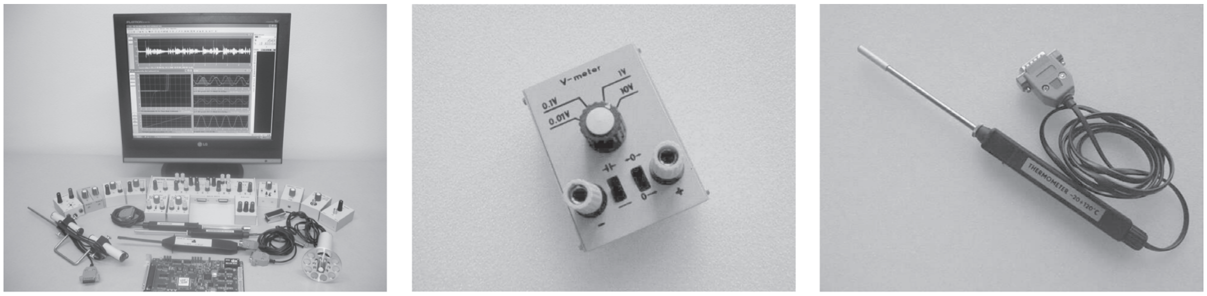
The components of INTe-L are, based on our definition of INTe-L: remote e-experiments, e-simulations and e-textbooks. Let us briefly discuss these components.

Remote e-Experiments

This component includes remote (or possibly hands-on) experiments. The technical achievements of ICT enable the construction of Internet e-laboratories comprising a set of real interactive experiments, globally distributed, accessible from any Internet connected computer, using common web services (such as a web browser).

Many real remote e-laboratories across the Internet have provided experiments on real world

Figure 1. Internet school experimental system (ISES): Hardware with the main panel, interface card and incomplete set of modules (left); V-meter module - range 10 mV÷10 V.; thermometer-range –20 ^{o}c ÷ +120 ^{o}c (right)



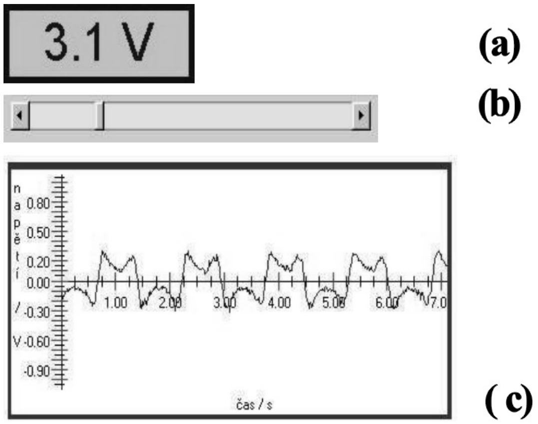
(a) (b) (c)

objects, supplying the client with the view of the experiment, an interactive environment for experiment control and resulting data for evaluation. Three European activities increased interest in remote physics laboratories: the project Pearl "Practical Experimentation by Accessible Remote Learning" (Cooper, 2005), the project Remote Farm (Cikic, Jeschke, Ludwig, Sinha & Thomsen, 2007), and the pioneering undertaking - RCL (Remotely controlled laboratories) in Kaiserslautern by Jodl (Gröber, Vetter, Eckert & Jodl, 2008). The acquired experience, an inventory of the state of the art and corresponding references on European and United States remote laboratories can be found in these projects.

With our work, we wanted to combine these efforts in a constructive way. We know, from our own long-lasting experience, that once the university or the department and/or their teachers decide to build the remote experiments (RE), the main obstacle is often not the financial requirements of the RE but the LiLa–Library of Laboratories (http://www.lila-project.org/) technicalities and the ICT know how and the corresponding knowledge about client-server communication. We offer a remedy to this situation and provide help with available hardware and software solutions enabling easy construction of both computer-based real experiments and their straightforward transformation to the real RE across the Internet (Schauer, Lustig, Dvořák & Ožvoldová, 2008a). The remedy is based on the scalable building set for the construction of natural science experiments, including physics - ISES (Internet School Experimental System) (Schauer, Kuritka & Lustig, 2006) and ready to use software for easy and simple creation of remote experiments - ISES WEB Control (Schauer, Ožvoldová & Lustig, 2009b). For a photo of the ISES Hardware, see www.ises.info and Figure 1.

The ISES computer interface card, with the inputs and outputs and the panel with plug-in slots for modules, provides an easy way of interfacing to virtually any PC-compatible computer. The card contains a 12-bit analogue-digital digital-analogue, time of conversion - 0.010 ms, DMA, and universal control board and a set of sensors (more than forty for physics, chemistry, biology, etc.). The system offers the possibility of simultaneous measurement and data display for eight input channels and process control via two analogue and four binary output channels. The analogue output channels work as programmable voltage sources (DC, AC with eight kinds of default signals, manual control or user defined signals). A maximum sampling frequency (100 kHz) enables the study of sounds or other high frequency signals. The ISES modules are easily interchangeable. The service program, provided with automatic calibration, automatically senses their presence and adjusts range accordingly. The

Figure 2. Examples of modular Java applets from the ISES WEB Control kit as building tools and blocks for remote experiments web control pages (a) display, (b) control slide, (c) graph



system is equipped with such modules as, for example: (Figure 1 left): voltage (10 mV ÷ 10 V), temperature (-20 °C ÷ +120 °C), current (±0.5 mA ÷ 1 A), resistance, capacitance, microphone, deviation sensing unit, adjustable preamplifier, light stop, current booster, relay switch, pressure meter, and many others. For chemistry, the electromagnetic valve for liquids and digital burette have been recently developed. The ISES service program enables the measurement of ten different channels (eight analogue inputs and two analogue outputs) simultaneously as well as four binary output channels. All these modules are fully programmable, using the programming panel. The depicted quantities either by measured modules or combinations of modules are arrived at through addition, subtraction, multiplication, division etc. The software provides data processing (integration, differentiation, fitting, approximation etc.). Exporting the data to another graphical processor is straightforward.

To enable classical server-client connections with the data transfer from the server to the client and vice versa for the control of the experiment by the client (experimenter), we built the software kit ISES WEB CONTROL (Schauer, Lustig & Ožvoldová, 2007). The WEB CONTROL kit creates an easy transformation of the computer oriented experiment based on the ISES system to RE. The software uses web services, web pages and client side Java support based on the copy-paste principle of the prefabricated building blocks (Figure 2.). An example of the webpage of a remote experiment is shown in Figure 3.

The general scheme for the creation of the server-client connection using the software ISES WEB CONTROL kit is depicted in Figure 4.

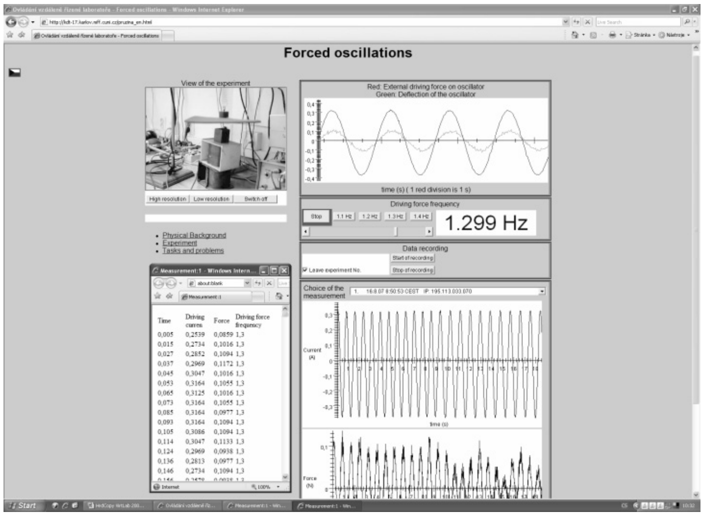
This approach enables the introduction of the complex study of real world phenomena based on data collection, their processing and evaluation, and comparison with models (see our e-laboratories on www.ises.info (Prague) and http://kf.truni.sk/remotelab (Trnava)).

e-Simulations

Within INTe-L interactive e-simulations play an important role and support new teaching methods and students' understanding of the solved problem. The e-simulations and modelling using both Internet available and home made Java or Flash applets are indispensable parts of INTe-L. They serve as demonstrations and explanations of observed phenomena and functions of the concomitant physics laws.

In our approach, we use applets, interactive animations generated in Java applets with physics content known as physlets. The Physlets collection cover a variety of different exercises: illustrations, explorations, and problems (Christian, 2004). Another excellent source of applets can be found on the http://phet.colorado.edu web page (Wieman, 2002, 2004). Surprisingly, the vast majority of applet simulations do not provide data output, which are needed for comparison of real experiments and models. For the multi-purpose simulation applets, we prepared our own simulations with the data outputs to support (or contradict) the measured data with the model (Ožvoldová, Schauer, Lustig & Dekar, 2008).

Figure 3. The web page on the client computer of the real remote experiment “Natural and driven oscillations” with live web camera view, frequency controls, graph of the measured and transferred data (http://kdt-17.karlov.mff.cuni.cz/pruzina_en.htm)



Time	Driving curren	Force	Driving force frequency
0,005	0,2539	0,0859	1,3
0,015	0,2734	0,1016	1,3
0,027	0,2852	0,1094	1,3
0,037	0,2969	0,1172	1,3
0,045	0,3047	0,1016	1,3
0,053	0,3164	0,1055	1,3
0,065	0,3125	0,1016	1,3
0,073	0,3164	0,1055	1,3
0,085	0,3164	0,0977	1,3
0,093	0,3164	0,1094	1,3
0,105	0,3086	0,1094	1,3
0,114	0,3047	0,1133	1,3
0,124	0,2969	0,0938	1,3
0,136	0,2813	0,0977	1,3
0,146	0,2734	0,1094	1,3

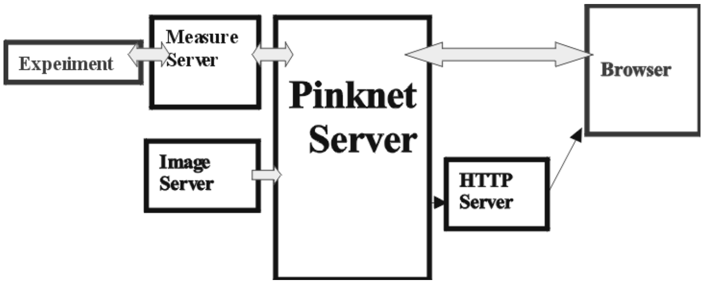
e-Textbooks

The e-textbook covers theory, solved problems and exercises, and includes a glossary for quick orientation of the theory covered, and multiple-choice tests with immediate evaluation of the acquired knowledge (Ožvoldová et.al 2006, 2007a). Recently, a course in mechanics using LMS MOODLE was introduced in the Faculty of Informatics, Tomas Bata University in Zlin, (http://vyuka.fai.utb.cz/login/index.php) using the general scheme of INTe-L, i.e. e-remote laboratory (www.ises.info), e-simulations and e-textbooks (Schauer, 2008b).

MECHANICS VIA INTE-L

Why did we concentrate on mechanics using the INTe-L strategy? Mechanics is the introductory and utmost important physics unit based on vector analysis and calculus. One of the main reasons to use INTe-L is to increase interest in the subject matter (which is sometimes boring as students openly declare). For INTe-L we needed computer

Figure 4. Schematic representation of the remote experiment setup with the Web server, Image Server, Measure Server and HTTP Relay Server



oriented either hands-on or remote e-experiments. To our surprise, we could find very few remote experiments on the web suitable for an introductory mechanics class, so we decided to build our own remote experiments. Only afterwards did we realize the main obstacle in building remote experiments in mechanics – the need to construct a simple dedicated small robot to execute simple mechanical movements. Another problem we encountered with some of the experiments was their short duration times and the corresponding dynamics of the experimental system and Internet data transfer. In these instances the system ISES was a great help, managing the data transfer with a 100 kHz sampling rate. As a result, we built PC-oriented experiments with quite different time scales, Free Fall (experiment time 0,5 s), Motion of a Body on a Horizontal and Inclined Plane (experiment time 4 s - 6 s), and Simple Pendulum and Oscillation (experiments time 1 s - 10000 s). Now we shall introduce three case studies with remote experiments for teaching and learning mechanics.

Case Study 1: Free Fall of a Body

The aim of this experiment is to study one dimensional motion of a body in the gravitation field of the Earth using the remote experiment Free Fall (http://remotelab4.truni.sk).

A free fall experiment in a tube is a popular experiment. It is based on the motion of a magnet in a tube inducing electromotive force in the coils distributed along the tube and giving corresponding signals (Kingman 2002). It is used in many modifications from a simple recording of the signal to the most sophisticated applications such as the fall in conductive media, where the motion may give surprising information on tube conductivity.

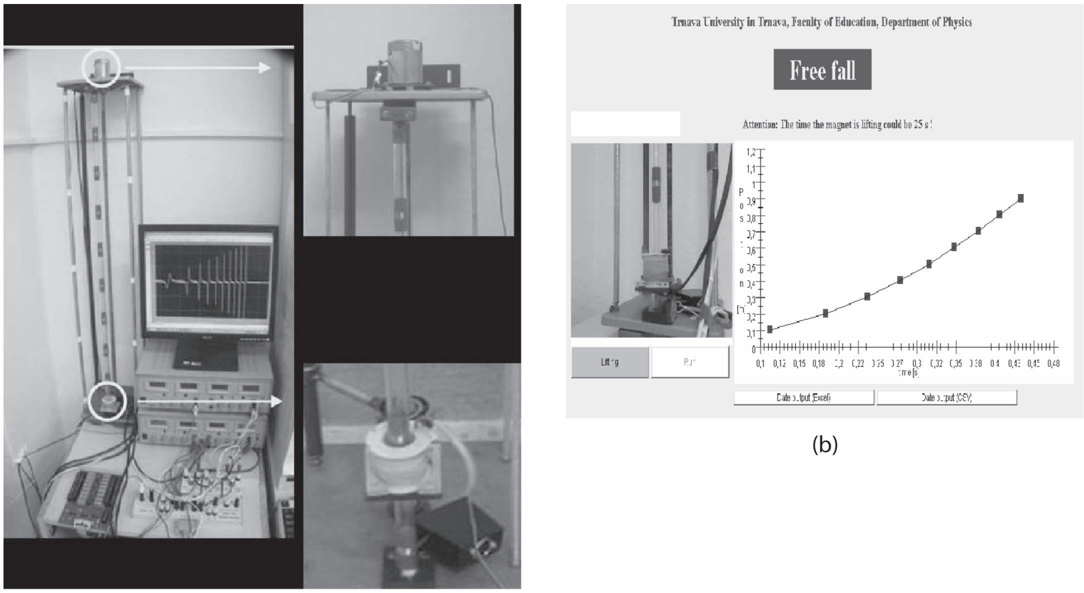
The first step was to build the hands on PC-based experiment using the ISES system, enabling both the hardware solutions (tube with coils ISES, signal V-meter module ISES) and software support (signal recording and data smoothing, processing - recording of chosen typical data, fitting, etc). Once the computer-based experiment was built, a second step in creating the remote experiment was needed - planning and programming the experiment. The detailed time and logic scheme of the experiment was, serving the proper functioning of the experiment and establishing the classic server-client connection with data transfer from the server to the client and vice versa for the control of the experiment by the client (experimenter). The drawn flow chard and software kit ISES WEB Control fits this purpose, resulting in the corresponding program and web page of the remote experiment http://remotelab4.truni.sk with live camera view and typical signal of the free fall in air recorded by the ISES system (Schauer, Lustig, Dvořák, & Ožvoldová, 2008b).

The most demanding task was to repeatedly lift the magnets to their starting position. For this purpose we devised and used an electromagnetic vessel, depicted in Figure 5, (detail in the middle, down), lifted by the screw driven by the step motor (detail in the upper middle). (Ožvoldová, Schauer, Žovinová & Beňo, 2009). Some technical details of the remote experiment are shown in Figure 6: the touch switch controlling the shut-down of the step motor, the relay switch controlling the running of the experiment and the control board with the module for voltage measurements.

Kinematic Aspects of Free Fall

The time dependence of the displacement for a falling magnet in a glass tube with nine evenly distributed coils is seen in Figure 7. Students can utilize the measured data to determine the acceleration of free fall *g* and discuss the result and its accuracy or to predict the changes with the position of the experiment on the Earth or other planets (http://www2.swgc.mun.ca/physics/physlets/mars_fall.html).

Figure 5. The remote experiment Free fall. (from left) The total arrangement and two details: The magnetic vessel lifted by the screw (lower), the step motor driving the screw, web page (to the right) of the remote experiment with live camera view, and recorded time dependence of the displacement. (http://remotelab4.truni.sk).



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Free fall

Attention: The time the magnet is lifting could be 25 s!

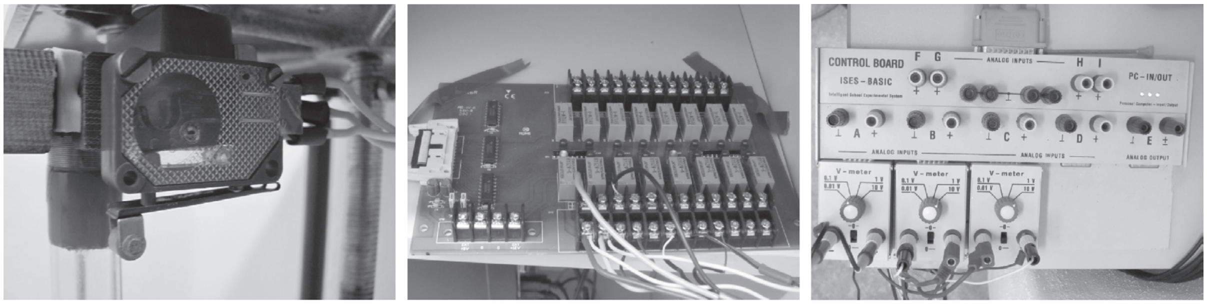
(a)

(b)

Dynamic Aspects- Forces Acting on the Falling Object

Before we started the transformation of the hands-on experiment to the remote one, the detailed evaluation of the data of the experiment systematically indicated differences between the results of other experiments on the free fall, caused by the presence of the dissipative forces (see Figure 8). We decided to introduce these dissipative forces during the experiment artificially, to control and measure them.

Figure 6. Technical details of the remote experiment (from left): The touch switch controlling the shutdown of the step motor, the relay switch controlling the running of the experiment, and the control board with the module for voltage measurements

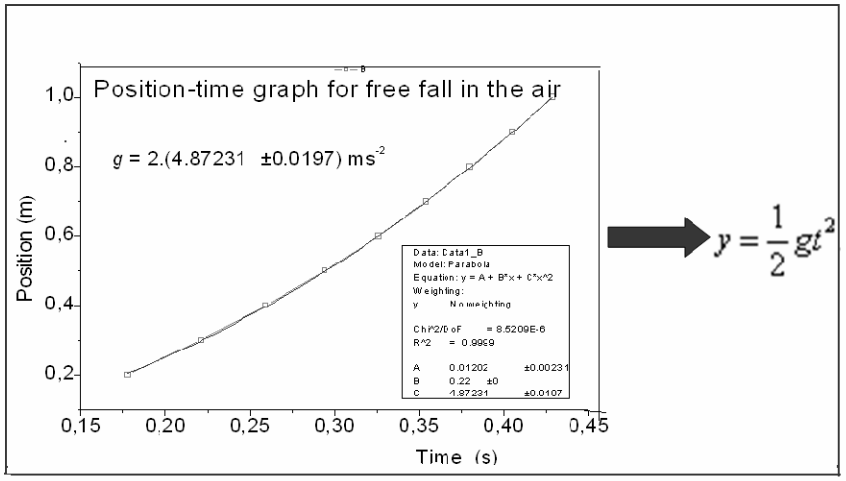


(a)

(b)

(c)

Figure 7. Time dependence of the falling magnet position with the acceleration of free fall g as an output



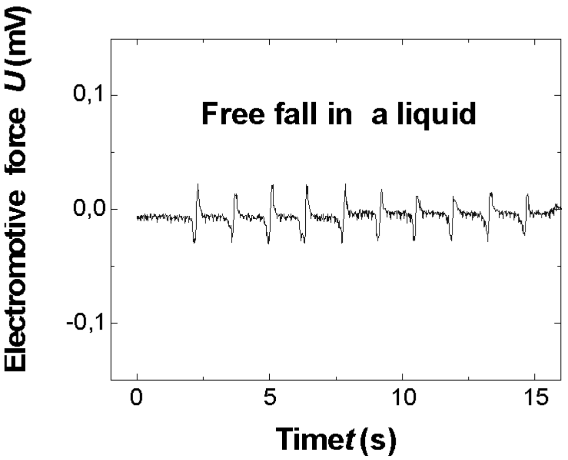
The theory of the free fall in dissipative media starts from the Newton differential equation of motion. The general solution for the motion in low pressure gasses (neglecting the buoyancy force) with the solution for velocity time dependence (assuming the positive direction for y is chosen to be upward) is given by equation (1) and for the motion in a viscous medium by equation (2)

$$m\frac{d^2y}{dt^2} = mg - k_1 v, \qquad \Rightarrow \qquad v(t)=\frac{mg}{k_1}\left(1-e^{-\frac{k_1 t}{m}}\right) \tag{1}$$

$$m\frac{d^2y}{dt^2} = mg - k_2 v^2, \Rightarrow v(t) = -\sqrt{\frac{k_2}{mg}}\tanh\left(\frac{k_2 g}{m}t\right) \tag{2}$$

where m is the falling body mass, t is the time and v is the velocity, and k_1 and k_2 are the corresponding coefficients of dynamical friction. The electromotive force time-graph for free fall in liquid shows that the magnet is falling with constant velocity due to forces acting upon it.

Figure 8. Free fall in a liquid



Energy Aspects

The student will become familiar with the concepts of kinetic energy, potential energy and total mechanical energy and its conservation. He/she can verify that the potential gravitational energy of a freely falling object decreases while its kinetic energy increases and the mechanical energy remains constant. These observations confirm that if the only acting force on a system is conservative then mechanical energy is conserved.

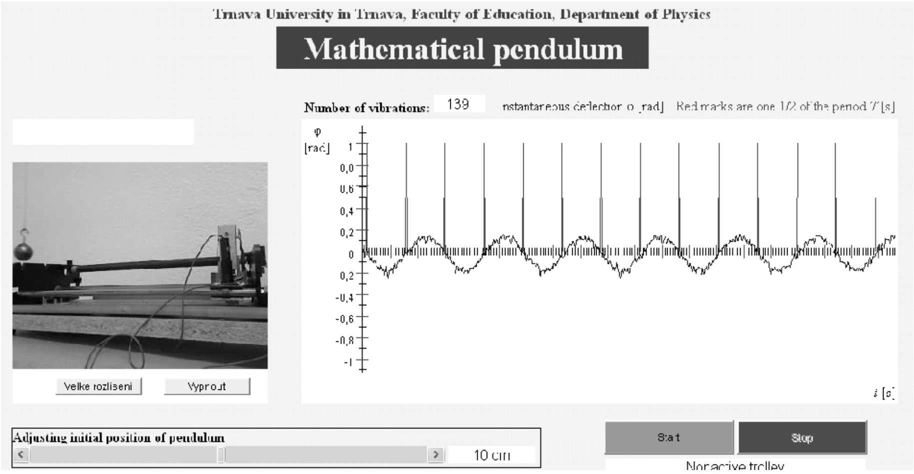
Case Study 2: Pendulum

The aim of the second experiment is to study curvilinear motion in two dimensions using the oscillatory motion of the simple pendulum based on the remote experiment from http://remotelab5.truni.sk, also called a mathematical pendulum (see Figure 9).

A simple (mathematical) pendulum is a class of experiment easy to implement and straightforward to demonstrate. The problems in deeper understanding start when the educator tries to put forward the mathematical formulation of its movement, not speaking about the concepts of the pendulum dynamics or energy. On the other hand, it is clear that the pendulum, even a simple one, may bring vast information, covering kinematics, dynamics of curved motion and its acceleration, energy - both kinetic, potential and total mechanical - and the role of dissipative forces that may be in this case minimized virtually to zero. The obvious obstacle in this approach, especially using the strategy of INTe-L, is the missing remote experiment on the pendulum with the data transfer with adjustable initial deflection and instantaneous deflection monitoring $\varphi = \varphi\ (t)$ (Schauer & Majerčík, 2009d).

The main idea of the reconstruction of the instantaneous deflection angle is the measurement of time representation of a couple of pull forces measured by the ISES dynamometer modules that correspond to the resolving of the pull into two fixed directions. These two forces enable the reconstruction of the instantaneous deflection angle $\varphi = \varphi\ (t)$. The technical details of the remote experiment are visible in Figure 10. – from the right top down, we see the ISES dynamometer, a board with two dynamometers D1 and D2, optical gate, the unit for the initial deflection control, and the module for setting the preselected initial deflection. The most demanding task of the transfer from hands-on to remote experiment was to give the pendulum the preselected initial deflection. This was accomplished by the module with the step motor controlled motion (1), position sensing resistor (2), and electromagnet fixed to the moving trolley (3) (see Figure 10- right, lower).

Figure 9. Web page of the remote experiment Mathematical pendulum; the unit for the initial deflection control and corresponding controls (left), graph of the instantaneous deflection with the labels of the individual swings (right)



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Mathematical pendulum

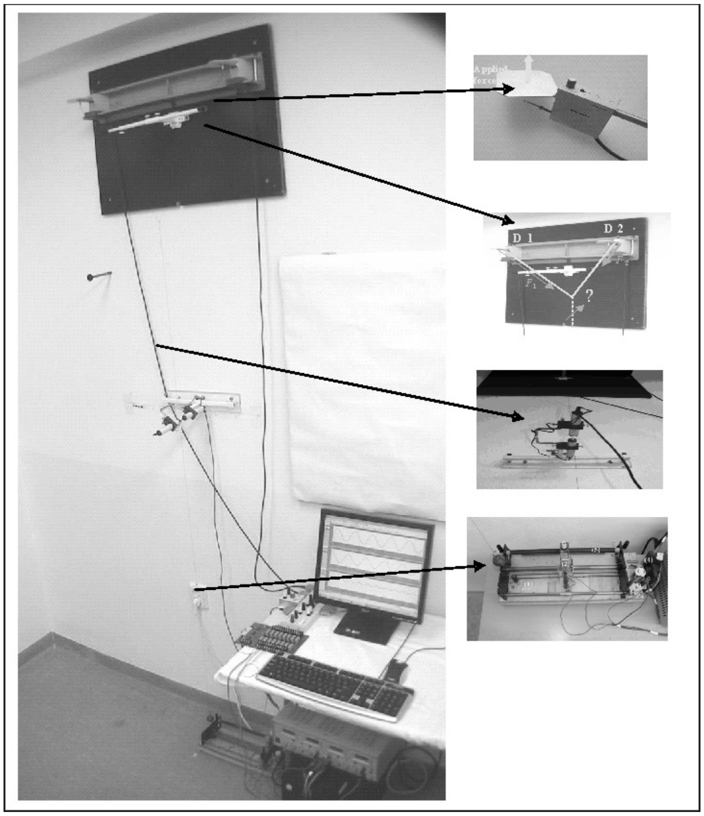
Number of vibrations: 139

nstantaneous deflection φ [rad] Red marks are one 1/2 of the period T [s]

Adjusting initial position of pendulum 10 cm

Nonactive trolley

Figure 10. Arrangement of the remote experiment and some technical details (right from top to bottom) - ISES dynamometer, - board with two dynamometers D1 and D2, - the unit for the initial deflection control, - optical gate and – the unit for setting the preselected initial deflection(with the step motor controlled motion (1), position sensing resistor (2) and electromagnet fixed to the moving trolley (3)



Kinematic Aspects of the Mathematical Pendulum

The basic property of any curvilinear motion is its non zero acceleration. This is due to the fact that the direction of the unit vector of the velocity is not constant and changes with time. For the determination of acceleration, it is necessary to know only the radius of the circle (the length of a pendulum r) and angular velocity $\omega(t) = d\varphi/dt$, where the instantaneous angle of deflection $\varphi(t)$ is given by

$$\varphi (t)) = \varphi_0 \sin (\Omega t), \tag{3}$$

where φ_0 is its amplitude and Ω is the angular frequency of the oscillatory motion of the pendulum.

$$\Omega = 2\pi f = \frac{2\pi}{T} = \sqrt{\frac{r}{g}}, \tag{4}$$

where r is the radius of the curvature of the trajectory, f is the frequency, T is the period and g is the acceleration due to the gravity. The representations of kinematics, dynamic and energy quantities of the simple pendulum are in Figure 11 and the time dependencies of the tangential a_t and normal a_n components of the acceleration can be seen in Figure 12.

All quantities, describing the mathematical pendulum, can be expressed in terms of the instantaneous deflection

$r = 2$ m, $\varphi_o = 0.1$ rad, $T = 3$ s, $m = 0.1$ kg

The velocity v, the tangential a_t and the normal a_n components of the acceleration are:

$$v = r\left(\frac{\mathrm{d}\phi}{\mathrm{d}t}\right) = r\left(\phi_0 \Omega \cos(\Omega t)\right) \tag{5}$$

$$a_t = \frac{\mathrm{d}v}{\mathrm{d}t} = r\alpha = \frac{\mathrm{d}^2\phi}{\mathrm{d}t^2} = -\, r\phi_0 \Omega^2 \sin(\Omega t) \tag{6}$$

And

$$a_n = r\omega^2 = r\left(\frac{\mathrm{d}\phi}{\mathrm{d}t}\right)^2 = r(\phi_0 \Omega \cos(\Omega t))^2 \tag{7}$$

Dynamic Aspects of the Mathematical Pendulum

Why does the simple pendulum move periodically? How can this movement be expressed in the language of mathematics? Are we able to write the equation of motion? In Figure 11 (middle) we can see the corresponding forces acting on the weight of the pendulum. For a simple pendulum we can resolve Newton's equation of motion $\Sigma \boldsymbol{F}_i = m\boldsymbol{a}$, where $\Sigma \boldsymbol{F}_i$ represents the vector sum of all the forces acting on the body. In our case for

$$x \text{ axis: } G \sin(-\varphi) = m a_t, \tag{8}$$

$$y \text{ axis: } T - G \cos(-\varphi) = m a_n, \tag{9}$$

where m is the mass of the pendulum, T is the pull in the suspension of the pendulum, G is the weight of the mass m. (Notice that $\varphi < 0$ in Figure 11.). For small angular displacements ($\varphi_o < 0.1$ rad) we can write approximately $\sin(\varphi) = \varphi$ and the equation (1) then reads

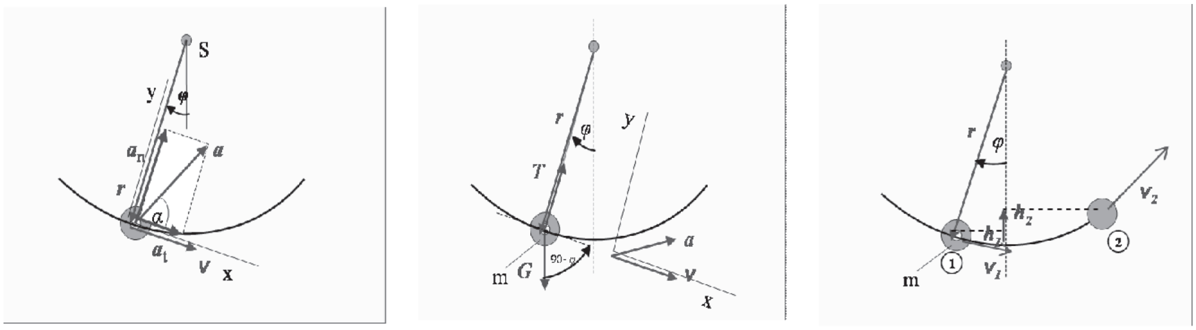
$$\frac{\mathrm{d}^2\phi}{\mathrm{d}t^2} = -\frac{g}{r}\phi, \tag{10}$$

with the solution

$$\varphi(t) = \varphi_0 \sin(\Omega t), \tag{11}$$

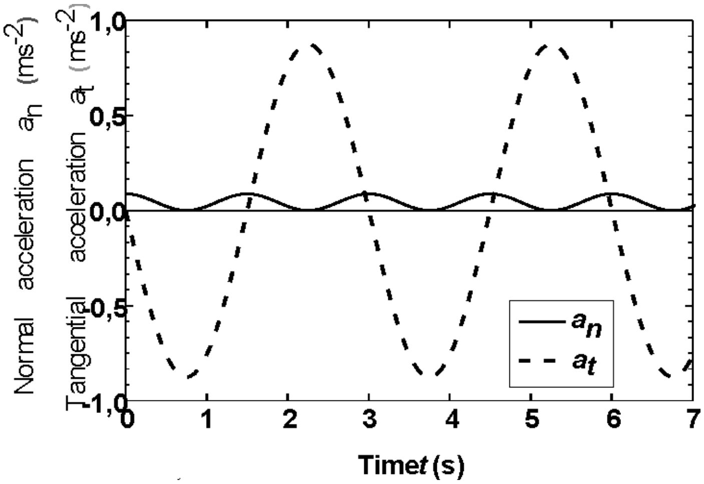
where the angular frequency of the oscillatory motion of the pendulum Ω is determined by equation (4).

Figure 11. The supporting diagrams of the pendulum (from left) for: kinematics, dynamic and energy elucidation



(a) (b) (c)

Figure 12. Tangential and normal acceleration of the simple pendulum



Using equations (7)–(11) we can write an important equation for the pull T in the suspension of the pendulum

$$T = m\,g \cos\,[\varphi_0 \sin(\Omega\, t)] + m\,r\,[\varphi_0\Omega \sin(\Omega\, t)]^2. \qquad (12)$$

Energy Aspects of the Mathematical Pendulum

Energy provides us with a simple method for deriving the expression that gives the velocity of a mass undergoing periodic motion as a function of position. The sum of the kinetic and the potential energy for any value of the angular displacement is constant and equals the total mechanical energy (Figure 13).

$$E_k + E_p = \frac{mv^2}{2} + mgh \qquad (13)$$

$$\frac{mr\left(\phi_0 \Omega \cos(\Omega t)\right)^2}{2} + mgr(1 - \cos(\phi_0 \sin(\Omega t)) = \text{const.}$$

For the pendulum height h above the reference level (see Figure 11, right), this is

$h = r\,(1\text{-}\cos\varphi)$.

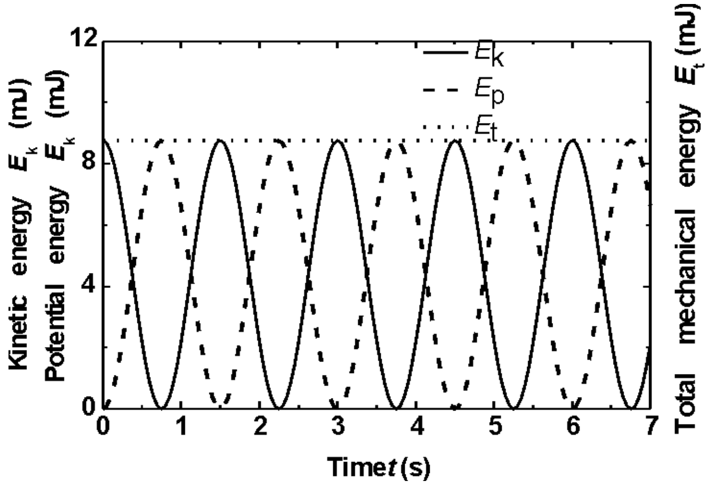
The increase in the potential energy ΔE_p equals the decrease of the kinetic energy $-\Delta E_k$ as shown in Figure 13. The energy description of the pendulum is suitably demonstrated by the University of Colorado simulation(s) (http://phet.colorado.edu/en/simulation/pendulum-lab), as well as Fendt´s pendulum simulation (http://www.walter-fendt.de/ph14sk/acceleration_sk.htm).

Case Study 3: Natural and Driven Oscillations

The goal of the third experiment is to demonstrate that oscillations constitute not only one of the most important parts of mechanics but physics and science as a whole, because the oscillatory movement is the basis of nearly all natural phenomena. The unifying model for real world systems may then be the model mass-spring system constituting the driven mechanical oscillator.

In our illustration of Integrated e-Learning in the practical teaching process, the starting point of the lecture on Natural and Driven Oscillations

Figure 13. Time dependence of the kinetic E_k and potential energy E_p of the pendulum $r = 2$ m, $\varphi_o = 0,1$ rad $T = 3$ s, $m = 0,1$ kg



is the remote experiment of the forced oscillations. This is available across the Internet in the e-laboratory project at http://www.ises.info/ where the student can find motivation, physical background, the schematic experimental arrangement, an assignment with ten tasks, and more details of the experimental arrangement. (A direct link to the experiment is available at http://kdt-17.karlov.mff.cuni.cz/pruzina_en.html).

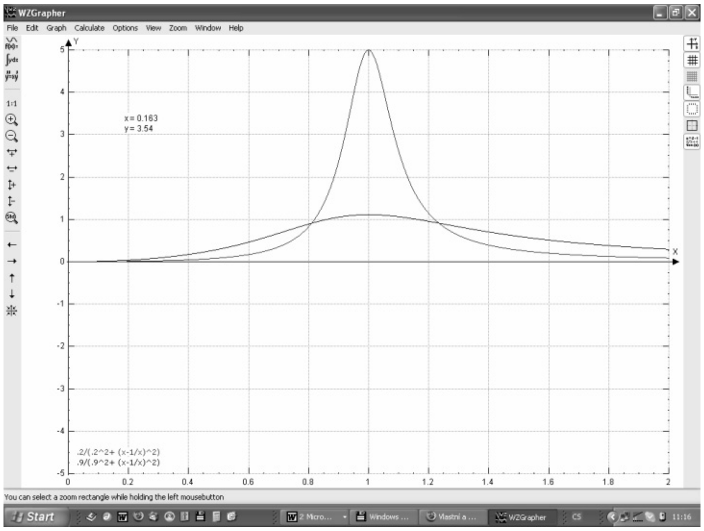
The web page for the real remote experiment "Natural and driven oscillations" includes a live web camera view, frequency controls, graph of the measured data and the transferred data; shown in Figure 3. Measured data gives information about frequency, the instantaneous value of the driving force, and the instantaneous deflection giving both the amplitude of the forced oscillations and their corresponding phase. The external driving force frequency is continuously variable.

The usage of the experiment is many fold; determining its own oscillation frequency, its damping, the resonance, the amplitude and phase transfer and energy transfer functions from the source of the driving force to the oscillator. If used in the students' laboratory, the students are encouraged to process the acquired data, find the physical quantities of the model oscillator, discuss the obtained results, and critically assess the errors of the measurements. Figure 14 depicts the energy transfer function from the driving force generator to the oscillator as a function of the frequency of the driving force, with two dampings as the parameters. The students are encouraged to find examples of the energy transfer in natural phenomena and in technical applications.

Such experiments are especially useful for self-study or during examinations, and may be very useful for part time studies, where laboratories are not standard.

Remote experiments augmented with virtual simulations create great potential for diverse education and individual learning support. That is why after real experimentation come e-simulations. The most frequently used simulation for oscillation is the e-simulation compiled by Fendt (http://www.walter-fendt.de/ph14e/resonance.htm). The Java applet provides the simple schematic dynamic view of the oscillator: its driving force (in the simulation red) and weight deflection (in the simulation blue) and the corresponding graphical time representations. The adjustable parameters are spring stiffness, mass of the weight and

Figure 14. Energy transfer function from the driving force generator to the oscillator force with damping as parameter (lower damping-upper curve and higher-lower curve)



You can select a zoom rectangle while holding the left mousebutton

attenuation and driving force frequency. In this simulation, nearly identical observations to that of the above-presented remote experiment may be carried out.

Often, we have utilized the PhET simulations presented by University of Colorado, especially the system Masses & Springs (http://phet.colorado.edu/en/simulation/mass-spring-lab) with kinematics, dynamics and energy displays of the phenomena (Wieman, 2004). For this purpose there are three springs with several hanging masses (some whose mass is unknown) with adjustable spring softness and friction and different gravitational environments. This applet provides ideas for further discussion between students and teachers.

Discussion

In the three above-mentioned case studies we have briefly outlined the utilization of the INTe-L strategy. All units of INTe-L within the basic course of physics were delivered to the students of Informatics via the LMS system MOODLE for easier studying. Remote experiments together with virtual simulations were used in all instances of teaching.

Teachers:

- *In lectures:* at the beginning of lectures to stimulate student interest in the corresponding area of study, - as demonstration experiments without the necessity of building experiments or demonstrations delivered by the interactive, board or data projector;
- *In seminars:* to introduce the problem solved, - to formulate the problem tasks, - to start group discussion;
- *During exams:* students have to explain the application of the theory and their understanding of the theory;
- Students:
- *In seminars:* students are connected via PC to the Internet and to all remote laboratories and to the MOODLE course of Mechanics;
- *In lab exercises*: all experiments in our remote laboratories are used as standard laboratory exercises with goals and as-

signments and laboratory reports in a similar way as other hands on laboratory experiments;

- *In project work:* experiments are the topics of the projects with the common goal to prove (disprove) the operative physics laws using data collection and then to evaluate and present the findings;
- *During self study:* where the course material is augmented with links to remote and virtual experiments as a study aid in the mastering of the theory.

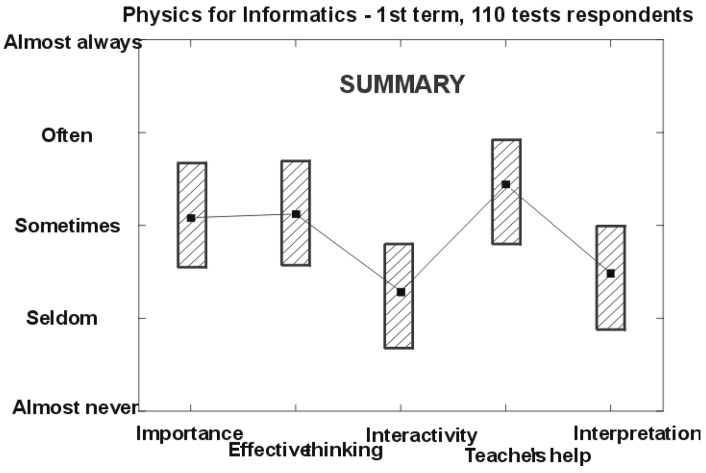
During our courses we minimize the number of experiments and simulations but try to keep them in all forms of teaching. As we have found, the prerequisites for the classroom usage of INTe-L are the carefully prepared supporting materials, the cooperative interplay of all teachers and instructors in lectures, seminars and laboratory exercises and the perfect function of all components of ICT.

For feedback on the effectiveness of the whole course we used the standard COLLES (Constructivist On-Line Learning Environment Survey, see Figure 15 for results) which provided the possibility to express views about the INTe-L course. One typical articulated view for all: "*Learning with real remote experiments and interactive simulation was easier and more interesting, teaching was more comprehensive.*"

Students appreciated detailed instruction and theory in every remote experiment as well free access to the study material. The LMS system allows better communication between the teacher and students and allows more time for individual work with students. With the same time allotted to both types of exercises, the students calculated more tasks in the computer-aided exercises.

Though it is still premature to summarize the impact and the effectiveness of the teaching with INTe-L technology based on remote experiments, we adhere to the opinion that e-laboratories and simulations can deeply improve the education in physics. For this reason, we suggested the method of Integrated e-Learning. The question arises, if INTe-L solves the present difficulties in physics teaching and complies with the findings, how do physics education researchers further improve the education process (Mayer, 2003). The prospective methods of teaching, including INTe-L, should comply with the general knowledge coming from cognitive research that (Bernhard, 2001; Rubin & Wenzel, 1996):

Figure 15. Results of standard COLLES inquiry on MOODLE course based INTe-L teaching strategy



1. Students should be provided with a suitable organizational structure, based on his/her prior thinking and experience and starting from their own research results. We should not simply be pouring facts on them and not addressing the simple questions "what", but rather "why". On top of this, previous knowledge must be carefully checked and examined and possible misconceptions dispelled. The ultimate goal in this respect should be active thinking, active exploratory work, guided by the active role of the teacher, and conditioned by the double-sided interaction of student – teacher.
2. The traditional teaching of "the rules" brings excessive amounts of new material that is far more than a typical person can process or learn. The more cognitive load the brain is given, the less effectively it can process anything and at the same time it is blocked from processing and mastering new ideas. This is one of the most well established and widely violated principles in education, including by many education researchers in their presentations. Any new method that should bring remedy to the situation and maximize learning should minimize the cognitive load by minimizing the amount of presented material. Presentations should be well organized structures and make the link to the already known ideas of the audience.
3. The third important criterion concerns the students and public beliefs about physics education and the importance of physics for society. If the belief about the purely abstract nature of physics and its not addressing the problems of the real world prevail, it deeply influences the approach towards the physics as a subject and the necessity of its mastery.

How does the INTe-L address these three criteria? The first above-mentioned criterion is met by-INTe-L from its starting point, observations, irrespective of whether it is a traditional computer-based laboratory, remote real e-laboratory across the Internet or a virtual e-laboratory (Lustig, Schauer & Ožvoldová, 2007). The real experiments strongly support the examination of the real world. On the other hand, the virtual laboratories or simulations support an interactive approach, employ dynamic feedback, follow a constructivist approach, provide a creative workplace, make explicit otherwise inaccessible models or phenomena, and inspire students positively (Finkelstein, Adams, Keller, Perkins, Wieman & the PhET Team, 2006).

The cognitive load in INTe-L is limited by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive, offering significant advantages in the individual rates of teaching progress. Traditional teaching scenarios cannot satisfy this requirement, particularly because of cognitive capacity issues. INTe-L environments meet these needs. The possibility of making abstract objects and concepts tangible by application to real and virtual laboratories demonstrates this qualitative change in education and addresses the diminishing of the cognitive load of students (Thomsen, Jeschke, Pfeiffer & Seiler, 2005).

In the fulfillment of the third criterion, INTe-L helps develop the qualities and skills the students acquire studying physics courses for their future study and professional careers. In practical teaching it means avoiding assigning problems that are graded strictly on a final number, or that can be done by plugging the correct numbers into a given procedure or formula. The fault in this common approach can teach students that solving physics problems is only about memorization and coming up with a correct number, whereas reasoning and seeing if the answer makes sense are irrelevant. The good news is that courses that make rather modest changes to explicitly address student beliefs have avoided the usual negative shifts. The INTe-L strategy introduces the physics ideas in terms of real-world situations or devices with which the students are familiar; recasting homework and exam problems into a form in which the answer is of some obvious utility rather than an abstract number, making sense and reflecting explicit parts of in-class activities, homework, and exams.

Technologies are a prerequisite for the continuous integration of internationalized studies: transparency of course content forms the basis for the international recognition of academic achievements, eases the formulation of rules of acknowledgement for studies in foreign countries, making a stay abroad considerably easier to manage and realize. Geographical proximity, previously a pre-requisite for intensive cooperation, is diminishing in impact.

Application of new media and new technologies has resulted in a significant impact on research. Today ICT is the technical foundation to access scientific sources and data. Interdisciplinary questions are getting more important and the possibility for interdisciplinary communication and cooperation plays a significant role.

FUTURE RESEARCH DIRECTIONS

The examination of the effectiveness of INTe-L is under way. For this purpose we apply standard pedagogical methods of inquiry and study questionnaires, the log-in protocols in remote experiments, and records of remote experiment measurements. Our ultimate goal is to prepare a basic physics course curriculum with the above mentioned scheme, using the remote e-experiments, e-simulations and e-textbook. For this, the corresponding set of remote experiments has been prepared in Prague (see www.ises.info) "Standing waves in the resonator", "Magnetic field generation and mapping", "Electrochemical sources of energy", and "Free fall in gasses and liquids. " These join those already functioning: "Controlling of the liquid level", "Monitoring the environment in Prague", "The electromagnetic induction", "The forced mechanical oscillator", "Diffraction of micro-objects", "the Heisenberg principle of uncertainty", and "Characterization of the photovoltaic device."

A second e-laboratory of remote experiments was built at University of Trnava (Slovak Republic) (http://kf.truni.sk/remotelab or http://remotelab*N*.truni.sk, where N = 1, 2, ….5) Environmental monitoring in Trnava N = 1, Electrochemical cell, N = 2, Energy transfer in oscillator (N = 3), Free fall (N = 4) and Mathematical pendulum (N = 5).

A third laboratory is being constructed in Zlin, where students of Applied Informatics at Tomas Bata University have built their first ISES and ISES WEB CONTROL KIT remote experiments (see Water management http://195.178.94.141 and Photovoltaic cell http://195.178.94.142) and student physics server (http://195.178.94.31). The great advantage is the support of the university authorities and the accreditation commission for these activities. The infrastructure of the teaching process must be changed accordingly. The whole potential offered by the INTe-L will be realized only if it is embedded in the existing academic structure.

After several years of working with INTe-L in practical teaching and learning we are engaged in its improvement in three major directions, namely

- Increasing the bilateral and multilateral communication teacher – student, student - student(s) in all forms of education as proposed by Hake in his Socratic pedagogy (Hake, 1998; 2007), but especially by adding collaborative features to MOODLE along the lines suggested in (Bochicchio & Longo, 2009) using the principles of the Web Collaborative Laboratory.
- Embedding the remote laboratories in the collaborative lab activities (Maiti, 2010), using the principles of Computer-Supported Collaborative Learning.
- Increasing the "short range" feedback in lectures by introducing the voting system ("clippers") as suggested by e.g. (Perkins & Turpen, 2009). The only problem to be

solved is the capacity of the system for 150- 200 students in the class resulting in awkwardness in operation. The feedback in seminars has been introduced by class management system, as every students working place in a typical physics class (and laboratory as well) is equipped with a web connected PC. We intend to introduce systematically as the measure of the average effectiveness of a course in promoting conceptual understanding the average normalized gain <g> defined as the ratio of the actual average gain (%<post> – %<pre>) to the maximum possible average gain (Hake, 1998).

CONCLUSION

Our work utilizes the ISES system to combine remote e-laboratories together with simulations are transforming physics education... In general, INTe-L complies with the general criteria physics education researchers suggest for the effectiveness of the education process:

1. INTe-L provides a suitable organizational structure, based on the student's prior thinking and experience.
2. INTe-L reduces the cognitive load by supporting the individual comprehension processes offering manifold accesses to knowledge and being individually adaptive.
3. INTe-L positively addresses the widely-held beliefs about physics education and the importance of physics for society. ICT supported education via real remote experiments together with interactive applets definitely increases students' interest in science and technical disciplines and real world phenomena.
4. The INTe-L approach supports development of the ability to solve real problems and creates an attractive and more interesting method of delivery of acquired knowledge, which can be used in an active manner among students.

INTe-L, as a new strategy of education based on e-experiments calls for deep changes in the university life as the infrastructure of the teaching process must be changed accordingly. The fulfillment of the whole potential offered by the INTe-L may be employed only if it is embedded in the academic structure.

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REFERENCES

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado learning attitudes about science survey. *Phys. Rev. Spec. Topics - Phys. Educ. Res.*, *2*, 010101.

Arons, A. B. (Ed.). (1990). *A guide to introductory physics teaching. American Association of Physics Teachers 1977*. New York, NY: Wiley.

Bernhard, J. (2001). Does active engagement curricula give long-lived conceptual understanding? In R. Pinto & S. Surinach (Eds.), *Physics teacher education beyond 2000* (pp. 749–752). Paris, France: Elsevier. Retrieved October 14, 2010, from http://www.ncsu.edu/sciencejunction/route/professional/labgoals.html

Bochicchio, M. A., & Longo, A. (2009). Hands-on remote labs: Collaborative Web laboratories as a case study for IT engineering classes. *IEEE Transactions on Learning Technologies*, *2*(4), 320–330. doi:10.1109/TLT.2009.30

Christian, W., & Belloni, M. (2004). *Physlet® Physics: Interactive illustrations, explorations and problems for introductory physics*. Prentice Hall. Retrieved July 10, 2010, from http://webphysics.davidson.edu/applets/Applets.html

Cikic, S., Jeschke, S., Ludwig, N., Sinha, U., & Thomsen, C. (2007). Networked experiments and scientific resource sharing in cooperative knowledge spaces. *Interactive Technology and Smart Education*, *4*(1), 19–30. doi:10.1108/17415650780000074

Cooper, M. (2005). Remote laboratories in teaching and learning – Issues impinging on widespread adoption in science and engineering education. *International Journal of Online Engineering*, *1*(1).

Domin, D. S. (1999). A review of laboratory instruction styles. *Journal of Chemical Education*, *76*, 543–547. doi:10.1021/ed076p543

Feisel, L. D., & Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education*, *93*, 121.

Fendt, W. (2002). *Java Applets on physics.* Retrieved July 10, 2010, from http://www.walter-fendt.de/ph14e/resonance.htm

Finkelstein, N. D., Adams, W., Keller, C., Perkins, K., & Wieman, C. (2006). High-tech tools for teaching physics: The physics education technology project. *MERLOT Journal of Online Learning and Teaching*, *2*(3), 109.

Gröber, S., Vetter, M., Eckert, B., & Jodl, H. J. (2007). Experimenting from a distance – Remotely Controlled Laboratory (RCL). *European Journal of Physics*, *28*(5), 127–141. doi:10.1088/0143-0807/28/3/S12

Gröber, S., Vetter, M., Eckert, B., & Jodl, H. J. (2008). Remotely controlled laboratories: Aims, examples, and experience. *American Journal of Physics, 76.* Retrieved September 14, 2009, from http://rcl.physik.unikl.de/docs/Remotely_controlled_laboratories-Aims_examples_and_experiences_AJP_special_issue_76%282008%29.pdf

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64. doi:10.1119/1.18809

Hake, R. R. (2007). Six lessons from the physics education reform effort. *Latin American Journal of Physics Education*, *1*(1), 24.

Jørgensen, H. D., Rolfsen, R. K., & Krogstie, J. (2004). Process-integrated e-learning. In *Proceedings of Workplace Learning – from the Learners Perspectives, WL 2004*, Copenhagen 25-27 November.

Kingman, R., Rowland, S. C., & Popescu, S. (2002). An experimental observation of Faraday's law of induction. *American Journal of Physics*, *70*(6), 595–598. doi:10.1119/1.1405504

Lustig, F., Schauer, F., & Ožvoldová, M. (2007). E-labs in engineering education: Classical, real remote or virtual? *Conference ICTE 2007* (pp.107-116). Technical University of Ostrava, Rožnov pod Radhoštěm.

Maiti, N. (2010). NETLab: An online laboratory management system. *International Journal of Online Engineering*, *6*(2), 31–36.

Mayer, R. (2003). *Learning and instruction*. Upper Saddle River, NJ: Merrill.

McDermott, L. C., & Redish, E. F. (1999). Resource letter: PER-1: Physics education research. *American Journal of Physics*, *67*(9), 755. doi:10.1119/1.19122

Oliver, M., & Trigwell, K. (2005). Can blended learning be redeemed? *E-learning*, *2*(1), 17.

Ožvoldová, M., Černanský, P., Červeň, I., Budinský, J., & Riedlmajer, R. (2006). Introduction into engineering physics - A multimedia CD tool for students entering the Slovak engineering universities. *Innovations 2006: World Innovations in Engineering Education and Research, iNEER Special Volume* (pp. 228–234). Virginia, USA.

Ožvoldová, M., Červeň, I., Dillinger, J., Halúsková, S., Laurinc, V., & Holá, O. … Beňo, M. (2007). *Multimedia university textbook on physics part 1.* University of Trnava, Faculty of Education, Trnava, Slovak Republic.

Ožvoldová, M., Schauer, F., Čerňanský, P., Gerhatová, Ž., Tkáč, L., & Beňo, M. (2010). *1st Slovak Internet Natural Sciences Remote e-Laboratory (INRe-L).* REV - Remote Engineering & Virtual Instrumentation Conference June 29 – July 2, 2010, Stockholm, Sweden.

Ožvoldová, M., Schauer, F., Lustig, M., & Dekar, M. (2008). Real remote mass-Spring laboratory experiments across Internet-inherent P E-learning of oscillations. *International Journal of Online Engineering*, *4*(1).

Ožvoldová, M., Schauer, F., Žovinová, M., & Beňo, M. (2009). Real interactive free fall experiment with data collection and transfer across Internet. MPTL 14. In C. Cassan (Ed.), *Proceeding of International Conference Multimedia in Physics Teaching and Learning Conference*, Litho Stampa, University of Udine, Italy. Retrieved July 10, 2010, from http://www.fisica.uniud.it/URDF/mptl14/ftp/full_text/T6_75%20Full%20Paper.pdf

Perkins, K. K., & Turpen, C. (2009). Student perspectives on using clickers in upper-division physics courses. *Physics Education Research Conference 2009, Part of the PER Conference series, 1179* (pp. 225-228). Ann Arbor, Michigan, July 29-30.

Procter, C. (2003). *Blended learning in practice education in a changing environment*. University of Salford, Retrieved July 14, 2010, from http://www.edu.salford.ac.uk/her/

Rubin, D. C., & Wenzel, A. E. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological Review*, *103*(4), 734. doi:10.1037/0033-295X.103.4.734

Schauer, F. (2008b). *INTe-L Moodle course of physics in the Faculty of Informatics, Tomas Bata University in Zlin, mechanics*. Retrieved from http://vyuka.fai.utb.cz/login/index.php

Schauer, F., Kuritka, I., & Lustig, F. (2006). Creative laboratory experiments for basic physics using computer data collection and evaluation exemplified on the intelligent school experimental system (ISES). *Innovations 2006: World Innovations in Engineering Education and Research, iNEER Special Volume* (pp. 305-312). Virginia, USA.

Schauer, F., Lustig, F., Dvořak, J., & Ožvoldová, M. (2008a). An easy-to-build remote laboratory with data transfer using the internet school experimental system. *European Journal of Physics*, *29*, 753–765. doi:10.1088/0143-0807/29/4/010

Schauer, F., Lustig, F., & Ožvoldová, M. (2009b). ISES -Internet School Experimental System for computer-based laboratories in physics. In Aung, W. (Ed.), *Innovation 2009, World Innovations in Engineering Education and Research, USA, iNEER Special Vol* (pp. 109–118). Arlington, VA, USA.

Schauer, F., & Majerčík, P. (2009c). Real interactive pendulum experiment with data collection and transfer across internet. In C. Cassan, (Ed.), *MPTL 14, Proceedings of International Conference Multimedia in Physics Teaching and Learning Conference*, Litho Stampa, University of Udine, Italy. Retrieved July 10, 2010, from http://www.fisica.uniud.it/URDF/mptl14/ftp/full_text/T6_74%20Full%20Paper.pdf

Schauer, F., Ožvoldová, M., & Lustig, F. (2009a). Integrated e-learning – New strategy of cognition of real world in teaching physics. *Innovations 2009: World Innovations in Engineering Education and Research, iNEER Special Volume* (pp. 119-135). Virginia, USA.

Schumacher, D. (2007). Student undergraduate laboratory and project work. *European Journal of Physics*, *28*(5).

Thomsen, C., Jeschke, S., Pfeiffer, O., & Seiler, R. (2005). *e-Volution: eLTR - Technologies and their impact on traditional universities*. Conference EDUCA online, ISWE GmBH, Berlin.

Wieman, C. (2002). *CU Nobel laureate Carl Wieman launches project to prove physics and science education*. Retrieved October 28, 2002, from http://www.colorado.edu/news/releases/2002/503.html

Wieman, C. (2004). *The physics educational technology*. Retrieved July 10, 2004, from http://phet.colorado.edu/

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science*, *322*, 682–683. doi:10.1126/science.1161948

Wieman, C. E., & Perkins, K. (2005). Transforming physics education. *Physics Today*, *58*, 26–41. doi:10.1063/1.2155756

ADDITIONAL READING

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006) New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. Physical Review Special Topics- Physics Education Research 2, 010101. Retrieved June 10, 2010 from http://www.colorado.edu/sei/class/Perkins_PERC2005.pdf

Altherr, S., Wagner, A., Eckert, B., & Jodl, H. J. (2004). Multimedia material for teaching physics (search, evaluation and examples). *European Journal of Physics*, *25*, 7–14. doi:10.1088/0143-0807/25/1/002

Bacon, D., & Stewart, K. (2006). How fast do students forget what they learn in consumer behavior? A longitudinal study. *Journal of Marketing Education*, *28*(2), 181. doi:10.1177/0273475306291463

Barbera, J., Adams, W. K., Wieman, C. E., & Perkins, K. K. (2008). Modifying and Validating the Colorado Learning Attitudes about Science Survey for Use in Chemistry. *Journal of Chemical Education*, *85*, 1435–1439. doi:10.1021/ed085p1435

Bochicchio, M. A., & Longo, A. (2010). Adding Collaborative Remote Lab activities to Moodle. In *Proceedings of the Conf. REV*, 29 June - 2 July, p. 259, Stockholm.

Domínguez, M., Fuertes, J. J., Reguera, P., Prada, M. A., & Mor'an, A. (2008, July). Inter-University Network of Remote Laboratories? In *Proceedings of the 17th World Congress, The International Federation of Automatic Control*, 13624 -13628, Seoul, Korea.

Fiesel, L. D., & Rosa, A. J. (2005) The Role of the Laboratory in Undergraduate Engineering Education, Journal of Engineering Education, January 2005, 121-130. Retrieved June 10, 2009 from http://scholar.google.com/scholar?q=The+Role+of+the+Laboratory+in+Undegraduate+Engineering+Education,&hl=cs&as_sdt=0&as_vis=1&oi=scholart

Gerhátová, Ž. (2009). *Projected-based Education Using Integrated e-Learning,* Unpublished doctoral dissertation, Constantine the Philosopher University in Nitra, Slovak Republic

Gomes, L., & Garcia-Zubía, J. (2005). *Advances on remote laboratories and e-learning experiences*. Spain: University of Duesto.

Gröber, S., Vetter, M., Eckert, B., & Jodl, H. J. (2008). Remotely controlled laboratories: Aims, examples, and experience. *American Journal of Physics*, *76*(4 & 5), 374. doi:10.1119/1.2885058

Hake, R. R. (1998) Introduction to SDI Lab Teacher's Guides. Retrieved June 10, 2010 from http://www.physics.indiana.edu/~sdi/IntroTchGuide.pdf

Hunter, C., Wardell, S., & Wilkins, H. (2000). Introducing first-year students to some skills of investigatory laboratory work. *University Chemistry Education*, *4*, 14–17.

Jeschke, S., Scheel, H., Richter, T., & Thomsen, C. (2007). On Remote and Virtual Experiments in eLearning. *J. of Softw.*, *2*(6), 76.

Johnstone, A. H., Sleet, R. J., & Vianna, J. F. (1994). An information processing model of learning: Its application to an undergraduate laboratory course in chemistry. *Studies in Higher Education*, *19*, 77–87. doi:10.1080/03075079412331382163

Ožvoldová, M., Čerňanský, P., Schauer, F., & Lustig, F. (2006). Internet Remote Physics Experiments in Student's Laboratory. In Aung, W. (Ed.), *Innovation 2006, World Innovations in Engineering Education and Research, USA, iNEER Special* (*Vol. 2006*, pp. 297–304). Arlington, VA, USA.

Schauer, F., Lustig, F., & Ožvoldová, M. (2007). Remote Material Science Internet Experiments Exemplified on Solid State Photovoltaic Cell Characterization. *Journal of Materials Education*, *29*(3-4), 193–200.

KEY TERMS AND DEFINITIONS

Dynamics: Deals with the motion of bodies due to exerted forces.

Integrated e-Learning: (INTe-L)**:** The interactive strategy of teaching and learning based on the observation of real world phenomena by real e-experiments and e-simulations and on the principal features of the physic laws. It includes e-teaching tools as interactive e-textbooks and manuals and instructions which provide information and theoretical background for the understanding and quantification of observed phenomena.

Kinematics: The study of the motion of bodies, without asking for the reason for the motion.

Learning Management Systems (LMS): A software application for the administration, documentation, tracking, and reporting of training programs, classroom and online events, e-learning programs, and training content.

Mechanics: A part of physics that deals with the study of the interactions among bodies by forces.

Physlets: Interactive computer simulations concerning natural science problems, especially Physics, introduced by W. Christian and M. Belloni.

Process-Integrated e-Learning: A teaching process, where a closer integration between learning and work is achieved by rather simple means such as course design, organizational knowledge management, and information system customization. In this sense it has nothing to do with INTe-L proposed by the present authors.

Socratic Dialogue Inducing Courses: Physics courses with various innovations emphasizing interactive engagement of students as opposed to the traditional method. The basis is the set of questions that helps to shape and formulate the hypothesis concerning the observed phenomenon.